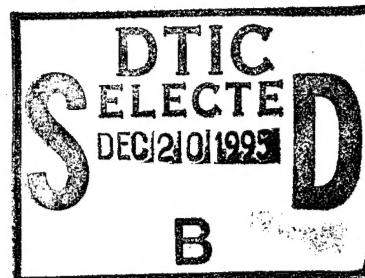


REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 05/15/79		3. REPORT TYPE AND DATES COVERED
4. TITLE AND SUBTITLE FLUORIDE REMOVAL BY LIME ADDITION FROM GROUNDWATER AT THE NORTHERN BOUNDARY OF ROCKY MOUNTAIN ARSENAL			5. FUNDING NUMBERS	
6. AUTHOR(S) THOMPSON, D.				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG, MS			8. PERFORMING ORGANIZATION REPORT NUMBER  81325R21	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT  APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) GROUND WATER AT THE NORTHERN BOUNDARY OF ROCKY MOUNTAIN ARSENAL HAS BEEN FOUND TO CONTAIN FLUORIDE IN CONCENTRATIONS IN EXCESS OF THE LEVEL RECOMMENDED BY THE COLORADO HEALTH DEPARTMENT. SEVERAL TREATMENT ALTERNATIVES FOR REMOVING THE FLUORIDE HAVE BEEN INVESTIGATED. THIS REPORT SUMMARIZES A STUDY CONDUCTED TO DETERMINE THE FEASIBILITY OF USING LIME PRECIPITATION FOR THE REMOVAL OF FLUORIDE FROM GROUND WATER AT THE NORTHERN BOUNDARY OF RMA. BASED ON THE RESULTS OF THIS STUDY, IT APPEARS THAT THIS PROCESS WOULD BE LESS COST EFFECTIVE THAN THE ACTIVATED ALUMINA PROCESS.				
14. SUBJECT TERMS  SODA ASH, TREATMENT, CHEMICALS			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED		18. SECURITY CLASSIFICATION OF THIS PAGE		19. SECURITY CLASSIFICATION OF ABSTRACT
20. LIMITATION OF ABSTRACT				

19951218 064





DEPARTMENT OF THE ARMY  
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS  
P. O. BOX 631  
VICKSBURG, MISSISSIPPI 39180

*original*  
**Original**

IN REPLY REFER TO:

WESEE

15 May 1979

Mr. Don Campbell  
U. S. Army Toxic and Hazardous Materials Agency  
Aberdeen Proving Ground, Maryland 210

81325R21

*original*

Dear Don:

Please find inclosed a copy of a short report concerning the study we conducted on fluoroide removal by lime addition from groundwater at the northern boundary of RMA. As we discussed previously, lime addition successfully reduced the fluoride concentration to the suggested standard, but based on the costs, the potential sludge disposal problems, and the probable variability in the effectiveness of the process, I think that activated alumina is the best choice for a system at RMA. If you have any questions, please contact me.

Sincerely yours,

*Douglas W. Thompson*

DOUGLAS W. THOMPSON  
Engineer  
Water Supply & Waste  
Treatment Group

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

Rocky Mountain Arsenal  
Information Center  
Commerce City, Colorado



**FILE COPY**

81525 R21

Fluoride Removal by Lime Addition from  
Groundwater at the Northern Boundary of  
Rocky Mountain Arsenal

1. Groundwater at the northern boundary of Rocky Mountain Arsenal (RMA) has been found to contain fluoride in concentrations in excess of the level recommended by the Colorado Health Department. Several treatment alternatives for removing the fluoride have been investigated. This report summarizes a study conducted to determine the feasibility of using lime precipitation for the removal of fluoride from groundwater at the northern boundary of RMA.
2. Lime and lime/soda ash addition were both investigated using a laboratory scale jar test apparatus. Equal sample volumes of water were placed in six beakers on a Bird multiple stirring unit and various amounts of chemicals were added to the samples. The samples were then mixed rapidly for one minute followed by slow mixing for 30 minutes. The precipitate formed was allowed to settle for 30 minutes after which time the supernatant was collected for analysis. Metal analysis were conducted using a Perkin-Elmer Model 300 atomic adsorption spectrophotometer. Fluoride analysis were conducted using an Orion specific ion electrode.
3. Analysis of a groundwater sample was conducted and the resulting characteristics are presented in Table 1. From these results, the stoichiometric dose of lime required was calculated to be 640 mg/l of CaO. Various percent excess dosages as indicated in Table 2 were added to the samples. The resulting fluoride concentrations along with pH, calcium, magnesium, and manganese are presented in Table 2.
4. The data shows that a dosage of 880 mg/l of CaO is required to reduce the concentration of fluoride to below the suggested limit of 1.8 mg/l. Increasing dosages of lime do not result in lowering the concentration of fluoride. Additional tests were conducted adding soda ash along with lime. Residual calcium concentrations were reduced but the residual fluoride concentrations remained the same.

5. Since calcium fluoride has a theoretical maximum solubility of approximately 8 mg/l of fluoride at pH 11, the removal of fluoride by lime addition in this study is probably attributable to adsorption of the fluoride ion onto metal hydroxide floc formed as a result of the lime addition. As indicated in Table 2, a significant amount of magnesium and manganese were removed at a lime dosage of 880 mg/l which corresponds to a significant decrease in the fluoride concentration. Similar results have been reported in the past where appreciable concentrations of naturally occurring magnesium have been found in the water being treated. In the absence of naturally occurring magnesium, the requirement for supplementary addition of magnesium generally makes the lime addition process for fluoride removal economically unfeasible. The addition of magnesium salts or other metal salts also results in an increase in the volume of sludge produced.

6. Chemical cost calculations were made based on the lime dosage requirement of 880 mg/l which is approximately 10 lbs/1000 gal. RMA is currently paying \$0.07/lb for lime in 50 lb bags. This amounts to \$0.70/1000 gal of water treated. Lime purchased in bulk quantities can be obtained for about \$0.025/lb to \$0.03/lb, which would result in chemical costs of between \$0.25/1000 gal and \$0.30/1000 gal. The process would require a clarifier capable of handling approximately 120,000 gal/day at existing flow rates and would produce approximately 1200 lbs/day (dry weight) of sludge. Also, sludge dewatering equipment would be required. The dewatered sludge must be disposed of in an environmentally acceptable manner.

7. Currently, a study\* is being conducted at RMA to determine the feasibility of using activated alumina for fluoride removal from the groundwater. In comparing the lime addition and activated alumina processes for fluoride removal the following differences should be noted. Lime addition was successful in reducing the fluoride concentration to just under the suggested limit. Therefore the process must be controlled

---

\*Rubel and Hager. "Feasibility Study for the Removal of Excess Fluoride from Activated Carbon Effluent." Prepared for Rocky Mountain Arsenal. Sept. 30, 1978.

precisely (constant monitoring) to insure that the residual fluoride concentration remains below the suggested limit. Since the process depends on the precipitation of metal hydroxides, variations in the characteristics of the water to be treated can cause significant changes in the efficiency of the removal process. The activated alumina process generally allows for more variation in the feed water since pH (which is continuously monitored) tends to be the controlling factor. The amount of sludge produced in the lime addition process is much greater than the amount resulting from the treatment of the regeneration waste stream associated with the activated alumina although the sludge from the latter usually contains a much higher concentration of fluoride. The lime addition process generally results in a greater loss of water from the process stream than does the activated alumina. And finally, the activated alumina process tends to be more economic than lime addition for treatment of water with fluoride concentrations of less than 10 mg/l.

3. Based on the results of this study concerning fluoride removal by lime addition, it appears that this process would be less cost effective than the activated alumina process. It is recommended that the activated alumina study be continued so as to provide the final information needed for scale-up of the activated alumina system for removal of fluoride from groundwater at the northern boundary of BMA.



Table 1

Characteristics of Groundwater from the  
Northern Boundary of Rocky Mountain Arsenal

<u>Parameter</u>	<u>Concentration(mg/l)</u>
pH	7.0
Total Alkalinity	300 (as $\text{CaCO}_3$ )
Total Hardness	420 (as $\text{CaCO}_3$ )
Sulfate	281
Chloride	340
Fluoride	3.85
Aluminum	0.14
Calcium	91.2
Iron	0.04
Magnesium	47.2
Manganese	1.14
Sodium	405

# Results of Lime Addition for Treatment of Groundwater from the Northern Boundary of Rocky Mountain Arsenal

Parameter	Lime Added								
	680* (6.25)**	720 (12.5)	760 (18.75)	800 (25.0)	880 (37.5)	960 (50.0)	1067 (67.0)	1120 (75.0)	1280 (100)
pH	9.6	9.7	9.5	10.2	11.7	12.2	12.3	12.3	12.4
Fluoride	2.78 +	2.70	2.64	2.62	1.69	1.74	1.75	1.76	1.71
Calcium	136. +	135.	118.	109.	241.	381.	380.	464.	556.
Magnesium	40.0 +	39.7	42.0	37.0	3.93	0.657	0.670	0.655	0.433
Manganese	0.404†	0.396	0.454	0.186	BDL††	BDL	BDL	BDL	BDL
* mg/l as CaO									
** Percent excess above stoichiometric									
+ mg/l									
†† <0.10 mg/l									